(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 233 234 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
29.09.2010 Bulletin 2010/39

(51) Int Cl.:
B23C 5/10 *(2006.01)*

(21) Application number: **10002881.0**

(22) Date of filing: **18.03.2010**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR
Designated Extension States:
AL BA ME RS

(30) Priority: **23.03.2009 JP 2009069860**

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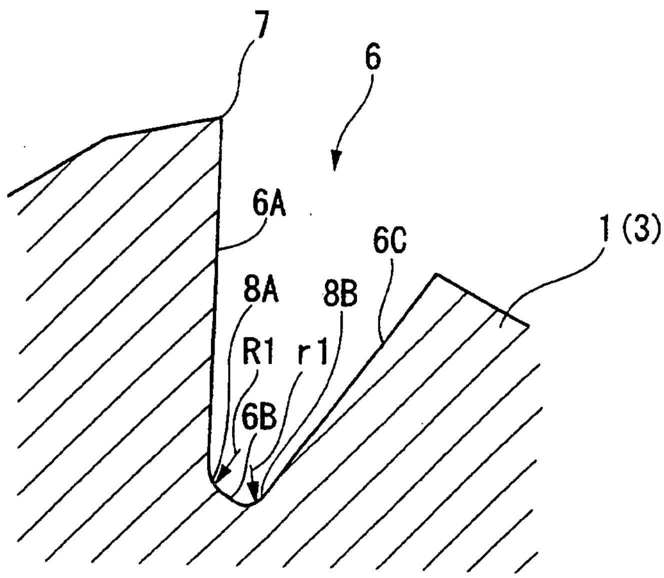
(54) End mill

(57) Provided is an end mill having a gash capable of ensuring excellent chip discharge performance and of preventing stress concentration, without losing the rigidity of a top portion of an end mill body.
In a cross-section perpendicular to an intersecting ridgeline between an end cutting edge rake face (6A) and a gash bottom face (6B) of a gash (6), the gash bottom face (6B) and the end cutting edge rake face (6A), and the gash bottom face (6B) and the gash wall face (6C) are respectively connected together by first and second connecting faces (8A and 8B). In the cross-section, these connecting faces have a form which is a concave curve or a substantially concave curve formed with straight lines. The radius of curvature (R1) of the concave curve or the radius of a circle inscribed in the straight lines forming the substantially concave curve about the first connecting face (8A) is larger than the radius of curvature (r1) of the concave curve or the radius of a circle inscribed in the straight lines forming the substantially concave curve about the second connecting face (8B).

[Fig. 2]



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Printed by Jouve, 75001 PARIS (FR)

Description

[Technical of the Invention]

[0001] The present invention relates to an end mill in which:

a flute is formed in the periphery of a top portion of an end mill body;
a gash is also formed in the top of the flute;
the wall face of the gash which faces the end mill rotating direction is an end cutting edge rake face; and
an end cutting edge is formed at the top of the wall face.

[Background of the Invention]

[0002] End mills, such as a square end mill, a radius end mill, and a ball-nosed end mill, are known: wherein a gash is formed in the top of a flute formed in the periphery of a top portion of an end mill body;
the gash has a shape which is like a shape formed by cutting out a wall face of the flute which faces an end mill rotating direction;
the wall face of the flute which faces an end mill rotating direction, is an end cutting edge rake face; and
an end cutting edge is formed along a top side ridge portion of the wall face.
[0003] For example, Patent Document 1 mentions such end mills wherein:

an intersecting ridgeline is between the end cutting edge rake face and the gash bottom face of the gash which faces the top side of the end mill body;
another intersecting ridgeline is between this gash bottom face and the gash wall face of the gash which faces the rear side in the end mill rotating direction;
a cross-section, which is perpendicular to a direction in which at least one of the intersecting ridgeline extends, shows that this intersecting ridgeline portion has a form like a concave curved shape;
the concave curve formed in the cross-section of the intersecting ridgeline has a radius of curvature; and
the radius of curvature at the outer peripheral side of the end mill body is longer than that at the inner peripheral side of the end mill body.

[0004] Also, Patent Document 2 mentions a ball-nosed end mill wherein:

a gash having a V-shape in a cross-section perpendicular to the flute of the gash, is provided at a hemispherical portion of an axial top; and
a radius cutting edge is formed along this gash.
Further, in this end mill,
the cutting-edge-rear-side side wall which
is one of side walls paired with each other in the V-shaped gash, and
is on the opposite side to the radius cutting edge;
has a concave surface which is smoothly concave in a cross-section perpendicular to the flute of the gash.

[Related Technical Document]

[Patent Document]

[0005]

[Patent Document 1] Japanese Unexamined Patent Application Publication No. 2005-125433
[Patent Document 2] Japanese Unexamined Patent Application Publication No. 2008-44038

[0006] In the end mill described in Patent Document 1, the intersecting ridgeline is between the end cutting edge rake face and the gash bottom face, and also the other intersecting ridgeline is between the gash bottom face and the gash wall face.
If one of the above two intersecting ridgelines has a form like a concave curved shape in a cross-section perpendicular to the direction in which the intersecting ridgeline extends;

the other intersecting ridgeline must have a form in which
the end cutting edge rake face and the gash bottom face intersect each other at a not so great angle, as if a face were sharply bent; and/or
the gash bottom face and the gash wall face intersect each other at a not so great angle, as if a face were sharply bent.
Therefore, the chips, which are generated by the end cutting edge and flow along the end cutting edge rake face, may cause clogging; and also this may hinder smooth chip discharging.

[0007] Additionally, in the above case wherein
the end cutting edge rake face and the gash bottom face intersect each other at an angle,
and/or
the gash bottom face and the gash wall face intersect each other at a not so great angle; stresses tend to concentrate at the intersecting ridgeline, and then the concentration of such stresses may cause a crack.
Thereby, the top portion of the end mill body formed between the gashes may be fractured.
In addition, problems similar to the above problems also exist in the end mill described in Patent Document 2: since, in this end mill,
the concave surface formed on the cutting-edge-rear-side side wall intersects the radius-cutting-edge-side side wall at a not so great angle; or
the concave surface is connected with the radius-cutting-edge-side side wall by a concave circular-arc having a

small radius.

[0008] Meanwhile, in the end mill described in Patent Document 1;

the intersecting ridgeline between the end cutting edge rake face and the gash bottom face has a form like a concave curved shape in a cross-section; and

the intersecting ridgeline between the gash bottom face and the gash wall face has a form like a concave curved shape in a cross-section too.

In particular, Fig. 3 of this Patent Document 1 shows that the gash bottom face itself becomes a concave circular-arc shape with a large radius of curvature, by which the end cutting edge rake face and the gash wall face are smoothly connected to each other. In such a case, the chips can flow smoothly; and the stress concentration does not arise.

[0009] In this case, however, since the end cutting edge rake face and the gash wall face need to be connected together by a concave circular-arc having a large radius of curvature, the width of the gash increases.

Additionally, the thickness (back metal) of the top portion of the end mill body decreases; and then the top portion loses its good rigidity.

The top portion of the end mill body

is located on the rear side of the end cutting edge in the end mill rotating direction,

and

is formed between the gashes.

Further, this problem becomes especially significant in an end mill wherein

the number of end cutting edges is three or more,
the number of gashes is also three or more, and
the top portion thereof is largely cut out to form the gashes.

[Summary of the Invention]

[0010] The present invention was made against such a background; and the object thereof is to provide an end mill having a gash capable of ensuring an excellent chip discharge performance and of preventing stress concentration, without losing the rigidity of a top portion of an end mill body as described above.

[0011] In order to solve the above problems, and achieve such an object, the invention provides an end mill in which:

an end mill body rotates on an axis;
a flute is formed in a periphery of a top portion of the end mill body;
a gash is formed in a top portion of the flute;
the gash has a shape which is like a shape formed by cutting out a wall face of the flute which faces an end mill rotating direction;
a wall face of the gash, which faces the end mill rotating direction, is an end cutting edge rake face; and an end cutting edge is formed along a top side ridge portion.
A gash bottom face of the gash is formed between the end cutting edge rake face and the wall face of the gash which faces the rear side in the end mill rotating direction.
Connecting faces connect the gash bottom face and the end cutting edge rake face, and connect the gash bottom face and the gash wall face.
The connecting faces have a concave curved shape or a substantially concave curved shape formed with straight lines in a cross-section perpendicular to an intersecting ridgeline between the end cutting edge rake face and the gash bottom face.
The connecting face, which connects the gash bottom face and the end cutting edge rake face, is a first connecting face.
The connecting face, which connects the gash bottom face and the gash wall face, is a second connecting face.
A radius of curvature of the first connecting face is larger than a radius of curvature of the second connecting face in the above cross-section; or
A radius of a circle inscribed in the straight lines forming the first connecting face is larger than a radius of a circle inscribed in the straight lines forming the second connecting face in the above cross-section.

[0012] In the end mill having the aforementioned construction; the end cutting edge rake face, the gash wall face, and the gash bottom face compose the gash. As mentioned previously, the connecting faces having a concave curved shape or a substantially concave curved shape formed with straight lines in a cross-section,

connect the gash bottom face and the end cutting edge rake face along an intersecting ridgeline between them, and

connect the gash bottom face and the gash wall face along an intersecting ridgeline between them, respectively.

Thus, if intersecting angles, between the end cutting edge rake face and the gash bottom face, and between the gash bottom face and the gash wall face, are the same; the stress concentration decreases, and also the chip discharge performance can be improved as compared to a case in which the above intersecting angles are not so great.

[0013] The connecting face which connects the gash bottom face and the end cutting edge rake face, is the first connecting face; and also

the connecting face which connects the gash bottom face and the gash wall face, is the second connecting face.

The first connecting face has a radius of curvature which is larger than that of the second connecting face in the above cross-section; or

the radius of a circle inscribed in the straight lines forming the first connecting face is larger than that of a circle inscribed in the straight lines forming the second connecting face in the above cross-section.

That is, the first connecting face, which connects the gash bottom face and the end cutting edge rake face, is formed so as to be curved more greatly than the second connecting face.
Thus, the chips can flow from the end cutting edge rake face, to the gash bottom face in good condition in a similar manner to the case where the whole gash bottom face has a concave circular-arc with a large radius of curvature in a cross-section.

[0014] On the other hand,
the second connecting face has a radius of curvature which is smaller than that of the first connecting face in the above cross-section; or
the radius of a circle inscribed in the straight lines forming the second connecting face, is smaller than that of a circle inscribed in the straight lines forming the first connecting face in the above cross-section.
Thus, the chips can flow smoothly even if the gash does not have such a large width.
Therefore, the end mill having the aforementioned construction can exhibit a good chip discharge performance by improving the flow of the chips, and can also exhibit good rigidity by maintaining the wall thickness of the top portion thereof as well.

[0015] Here, concerning the above first and second connecting faces, it is preferable that:

> the radius of curvature of the first connecting face is in the range of from 0.04×D to 0.08×D, or
> the radius of a circle inscribed in the straight lines forming the first connecting face is in
> the range of from 0.04×D to 0.08×D,
> in the cross-section.

D is the external diameter of the end cutting edge.
If the radius of curvature of the first connecting face, or the radius of curvature of the inscribed circle about the first connecting face, is smaller than this range; the chips cannot smoothly flow through the first connecting face. Further, since the radius of curvature of the second connecting face, or the radius of curvature of the inscribed circle about the second connecting face, is smaller than that of the first connecting face; chip clogging and/or stress concentration may arise thereat.
On the other hand, even if the radius of curvature of the first connecting face, or the radius of curvature of the inscribed circle about the first connecting face, is larger than this range; the radius of curvature of the second connecting face, or the radius of curvature of the inscribed circle about the second connecting face, need to be excessively small to avoid increasing the width of the gash.

[0016] Additionally, for the same reason,
the radius of curvature of the second connecting face is in the range of from 0.01×D to 0.05×D, or
the radius of a circle inscribed in the straight lines forming the second connecting face is in the range of from 0.01×D to 0.05×D, in the cross-section, preferably.
D is the external diameter of the end cutting edge.
That is, if the radius of curvature of the second connecting face or the radius of curvature of the inscribed circle about the second connecting face is smaller than this range, chip clogging and/or stress concentration at the second connecting face may arise.
On the other hand, if the radius of curvature of the second connecting face, or the radius of curvature of the inscribed circle about the second connecting face, is larger than this range; the radius of curvature of the first connecting face or the radius of curvature of the inscribed circle about the first connecting face need to be longer than that of the second connecting face, and then the width of the gash may increase.

[0017] In addition, as the motioned above,
since the gash having a small width enables the top portion of the end mill body to maintain good strength; applying this invention to an end mill in which three or more end cutting edges are formed at the top of the end mill body is particularly effective.
In other words, even if a gash has a large width, an end mill having such a gash, and having one or two end cutting edge(s) can hold a sufficient wall thickness for the top portion of the end mill body formed between the gash and the next gash on the rear side of the end cutting edge in the end mill rotating direction.
However, for an end mill having three or more end cutting edges, holding such a large wall thickness is difficult.

[0018] As described above, since a gash of the invention does not have such a large width; such a gash enables the top portion of the end mill body to improve its rigidity, and also
enables the chips generated by the end cutting edge to flow smoothly.
Thus, a good chip discharge performance can be secured; and also stress concentration can be prevented. Therefore, the top portion of the end mill body can become free from fractures; the tool life of the end mill is extended; and stable milling can be performed.

[Brief Description of the Drawings]

[0019]

> [Fig. 1] Fig. 1 is a side view with a partial sectional view showing a first embodiment of the invention.
> [Fig. 2] Fig. 2 is an AA magnified sectional view in Fig. 1.
> [Fig. 3] Fig. 3 is another magnified sectional view, equivalent to the AA magnified sectional view in Fig. 1, showing a second embodiment of the invention.

[Detailed description of the Preferred Embodiments]

[0020] In a first embodiment of the invention shown in Figs. 1 and 2, an end mill body 1
is made of a hard material, such as cemented carbide; and

has a substantially cylindrical shape in which an axis O is its center axis.

A rear end part (a right part in Fig. 1) of the end mill body is a shank part 2 having a cylindrical shape; and also a top part (a left part in Fig. 1) of the end mill body is a cutting edge part 3.

As the first step, the shank part 2 is fixed to a spindle of a machine tool. Further, when rotating the end mill 1 in an end mill rotating direction T on the axis O, and then feeding the end mill in a direction intersecting the axis O; the cutting edge part 3 cuts into a workpiece to machine it.

[0021] Three or more (four in this embodiment) flutes 4 in a helix shape in the reverse direction of the end mill rotating direction T around the axis O from the top side toward the rear end side, are formed in the periphery of the cutting edge part 3.

A cross-section perpendicular to the axis O shows that; wall faces of these flutes 4 facing the end mill rotating direction T, have a concave curved shape concave backward in the end mill rotating direction T. Also, periphery cutting edges 5 are formed along the periphery ridge portions on the cutting edge part, respectively.

Therefore, the wall faces become rake faces of the peripheral cutting edges 5, namely, peripheral cutting edge rake faces 4A.

In this embodiment, the four peripheral cutting edges 5 are formed helically in accordance with the helical shape of the flutes 4 in which the peripheral cutting edge rake faces 4A are formed.

[0022] On the other hand, gashes 6 which extend radially inward from the flutes 4, are formed at a top portion of the end mill body 1.

Wall faces of the gashes 6 facing the end mill rotating direction T, have a form which is like a shape formed by cutting out the wall face 4A at only the inner peripheral side of the wall face 4A, or from the inner peripheral side of the wall face 4A to the periphery of the end mill body 1.

End cutting edges 7 which extend radially inward from the tops of the peripheral cutting edges 5 toward the inner peripheral side of the end mill body 1, are formed along the top side ridge portions of the wall faces.

[0023] Accordingly, in this embodiment,

the wall faces of the gashes 6 which face the end mill rotating direction T, become rake faces of cutting edges 7, namely, end cutting edge rake faces 6A: and

the four end cutting edges 7 have a linear form which extends radially inward from the outer peripheral side of the top portion of the end mill body 1 towards the inner peripheral side thereof. The number of the end cutting edges 7 is three or more, the same as that of the peripheral cutting edges 5. In this embodiment, there are four end cutting edges 7.

Here, the end mill of this embodiment is a square end mill having a form in which:

> a rotational locus of each peripheral cutting edge 5 on the axis O is a substantially cylindrical shape having the axis O as its center; and
> the rotational locus of each peripheral cutting edge 5 intersects a rotational locus of each cutting edge 7 on the axis O at approximate right angles.

[0024] Moreover, each gash 6 includes:

> a gash bottom face 6B which is connected to the portion of the end cutting edge rake face 6A on the forward side in
> the end mill rotating direction T, and
> faces the top side of the end mill body 1 in the direction of the axis O;
> and
> a gash wall face 6C which is connected to the portion of the end cutting edge rake face 6B on the further forward side in the end mill rotating direction T, and faces the rear side in the end mill rotating direction T so as to face the gash bottom face 6A.

In this embodiment, the gash wall face 6C also has an even shape, and extends to the top side in the direction of the axis O so as to be apart from the end cutting edge rake face 6A as it goes to the top side. Therefore, a side view of the end mill body 1 shows that:

> the gash 6 is a V-shaped flute whose width increases gradually toward the top side; and also
> the gash 6 has a form whose width increases gradually toward the outer peripheral side.

[0025] In this embodiment, as shown in Fig. 2, a cross-section, which is perpendicular to an intersecting ridgeline between the end cutting edge rake face 6A and the gash bottom face 6B, shows that the end cutting edge rake face 6A and the gash bottom face 6B are smoothly connected together by a first connecting face 8A having a concave curved shape.

Also, as shown in Fig. 2, a cross-section, which is perpendicular to an intersecting ridgeline between the end cutting edge rake face 6A and the gash bottom face 6B, shows that the gash bottom face 6B and the gash wall face 6C are also connected together by a second connecting face 8B having a concave curved shape. Further, the above cross-section shows that:

> the radius of curvature R1 of a concave curve formed by the first connecting face 8A is larger than the radius of curvature r1 of a concave curve formed by the second connecting face 8B.
> The above intersecting ridgeline is an assumed ridgeline where the extended end cutting edge rake face 6A and the extended gash bottom face 6B intersect each other.

[0026] In this embodiment, the above cross-section shows that the first connecting face 8A and the second connecting face 8B have a form which is a concave circular-arc shape, respectively.

The radius of curvature R1 of the concave circular-arc formed by the first connecting face 8A, is set in the range of from 0.04×D to 0.08×D in the above cross-section; and

the radius of curvature r1 of the concave circular-arc formed by the second connecting face 8B, is set in the range of from 0.01×D to 0.05×D in the above cross-section, respectively.

Here, D is the external diameter of the end cutting edge 7.

In addition, the gash bottom face 6B may remain in an even shape between both first and second connecting faces 8A and 8B; or

the gash bottom face 6B may be a common tangent portion which both first and second connecting faces 8A and 8B having a concave curved shape in the cross-section touch smoothly.

[0027] In the end mill having such a construction,

the end cutting edge rake face 6A and the gash bottom face 6B do not intersect each other at an angle, but the first connecting face 8A having a concave curved shape in the cross-section connects them smoothly; and also the gash bottom face 6B and the gash wall face 6C of the gash 6 do not intersect each other at an angle, but the second connecting face 8A having a concave curved shape in the cross-section connects them smoothly. Thus, the stress caused by cutting force, etc. does not concentrate at the intersecting ridgeline. Further, the intersecting ridgeline becomes free from cracking caused by such stress concentration. Therefore, the end cutting edge 7 can be prevented from fracturing, and then the tool life of the end mill can be extended.

[0028] Furthermore, as mentioned above, in this embodiment,

the end cutting edge rake face 6A and the gash bottom face 6B do not intersect each other at an angle, but the first connecting face 8A having a concave curved shape in the cross-section connects them smoothly; and also the gash bottom face 6B and the gash wall face 6C of the gash 6 do not intersect each other at an angle, but the second connecting face 8A having a concave curved shape in the cross-section connects them smoothly.

Therefore, the chips, which are generated by the end cutting edge 7 and should flow out along the end cutting edge rake face 6A, can flow smoothly and can be discharged without the occurrence of chip clogging at the intersecting ridgeline between the end cutting edge rake face 6A and the gash bottom face 6B, or at the intersecting ridgeline between the gash bottom face 6B and the gash wall face 6C.

[0029] Moreover, the radius R1 of the first connecting face 8A which connects the end cutting edge rake face 6A and the gash bottom face 6B is larger than the radius r1 of the second connecting face 8B which connects the gash bottom face 6B and the gash wall face 6C.

Thus, while the chips are going from the first connecting face 8A to the second connecting face 8B; the chips gradually receive resistance force, and then the resistance force gradually makes the chips curl. Therefore, a great cutting resistance is not applied to the end mill body 1 compared to a case in which the chips receive resistance force in a short time, and then the resistance force makes the chips curl in a short time. This construction also can extend the tool life of the end mill, and then smooth cutting work can be performed in good conditions.

[0030] Also, as described above, the radius R1 of the first connecting face 8A is larger than the radius r1 of the second connecting face 8B. In other words, the radius r1 of the second connecting face 8B is smaller than the radius R1 of the first connecting face 8A.

In the end mill having the above construction,

compared to a case in which a connecting face having a large radius such as the radius R1 of the first connecting face 8A connects the gash bottom face 6B and the gash wall face 6C; a space between the gash wall face 6C and the end cutting edge rake face 6A, namely, the width of the gash 6, is required to be a size that is not so large.

[0031] Thus, the wall thickness of the top portion of the end mill body 1 formed between the gashes 6, which are adjacent to each other radially, can increase; and then the rigidity of the top portion of the end mill body 1 on the rear side in the end mill rotating direction T of the end cutting edge 7 also can be improved.

Therefore, the top portion of the end mill body 1 formed between the gashes 6 is reliably prevented from fracturing, and then the tool life of the end mill can be further extended.

These subjects are effective for an end mill in which

> the number of the end cutting edges 7 is three or more, such as this embodiment; and the wall thickness of the top portion of the end mill body 1 formed between the gashes 6 tends to decrease.

[0032] Next, Fig. 3

shows a second embodiment of the invention, and

is a sufficiently magnified view of a portion equivalent to the gash bottom face 6B of the first embodiment in a cross-sectional view perpendicular to the intersecting ridgeline between the end cutting edge rake face 6A and the gash bottom face 6B.

The parts common to those of the first embodiment have the same reference numerals as the first embodiment. Thus, description of such parts is omitted.

[0033] In the first embodiment, the first and second connecting faces 8A and 8B have a concave curved (concave circular-arc) shape in the cross-section.

On the other hand, in the second embodiment, first and second connecting faces 9A and 9B have a substantially concave curved shape formed with straight lines in the cross-section. In this shape, the cross-section shows that:

> the end cutting edge rake face 6A, the gash bottom face 6B, and the gash wall face 6C are straight lines; a first connecting face 9A formed with straight lines connects the end cutting edge rake face 6A and the

gash bottom face 6B;

a second connecting face 9B formed with straight lines connects the gash bottom face 6B and the gash wall face 6C;

the first connecting face 9A intersects the end cutting edge rake face 6A and the gash bottom face 6B at an obtuse angle respectively; and

the second connecting face 9B intersects the gash bottom face 6B and the gash wall face 6C at an obtuse angle respectively.

[0034] Additionally, radius R2 of a circle inscribed in the straight lines forming the first connecting face 9A is larger than radius r2 of a circle inscribed in the straight lines forming the second connecting face 9B.
In this embodiment, the radius R2 about the first connecting face 9A is set in the range of from $0.04\times D$ to $0.08\times D$, and the radius r2 about the second connecting face 9B is set in the range of from $0.01\times D$ to $0.05\times D$. D is the external diameter of the end cutting edge 7.
[0035] In this second embodiment, the end mill has a construction wherein the first and second connecting faces 9A and 9B having a substantially concave curved shape formed with straight lines intersect the end cutting edge rake face 6A, the gash bottom face 6B, and the gash wall face 6C at a great angle respectively in the cross-section.
Thus, such a construction can control the stress concentration, compared to a construction wherein:

the end cutting edge rake face 6A and the gash bottom face 6B intersect each other at a not so great angle; and/ or

the gash bottom face 6B and the gash wall face 6C intersect each other at a not so great angle.

Additionally, the chips generated by the end cutting edge 7 can flow out and go along the circular arc of a circle inscribed in the straight lines forming the first and second connecting faces 9A and 9B in the cross-section.
Thus, the chips can flow smoothly in a similar manner to the first embodiment in which the chips can flow along the concave curves (concave circular-arcs) forming the first and second connecting faces 9A and 9B in the cross-section.
[0036] Also, the radius R2 of a circle inscribed in the straight lines forming the first connecting face 9A is larger than the radius r2 of a circle inscribed in the straight lines forming the second connecting face 9B in the cross-section.
Thus, in a similar manner to the first embodiment, this construction

can control the increasing of cutting resistance by the chips;

can reduce the width of the gash 6; and

can prevent the end mill body 1 from fracturing.

The connecting faces 9A and 9B can be formed easily, compared to the first embodiment.

In the first embodiment,

the first connecting face 8A having a concave curved shape in a cross section, connects smoothly the end cutting edge rake face 6A and the gash bottom face 6B; and

the second connecting face 8B having a concave curved shape in a cross section, connects smoothly the gash bottom face 6B and the gash wall face 6C.

This is an advantage of this embodiment.

[0037] In addition, in this second embodiment, a construction is usable wherein, in the cross-section,
the first connecting face 9A has a straight line shape, and connects the end cutting edge rake face 6A and the gash bottom face 6B;
the second connecting face 9B has a straight line shape, and connects the gash bottom face 6B and the gash wall face 6C; and
the substantially concave curve is formed with the straight lines, namely, these connecting faces, the end cutting edge rake face 6A, the gash bottom face 6B, and the gash wall face 6C.
Also, another construction is usable wherein
the first connecting face 9A, which is formed with straight lines intersecting each other at an obtuse angle, connects the end cutting edge rake face 6A and the gash bottom face 6B; and
the second connecting face 9B, which is formed with straight lines intersecting each other at an obtuse angle, connects the gash bottom face 6B and the gash wall face 6C.
In the above two constructions, lines which
are two of the straight lines forming the substantially concave curve, and
are next to each other;
intersect each other at an obtuse angle of 120 deg. or more, preferably.
[0038] Additionally, in the first and second embodiments, in the cross-section,
if the radius of curvature R1 of a concave curve (concave circular-arc) of the first connecting face 8A is too small, or if the radius R2 of a circle inscribed in the straight lines forming the substantially concave curve, namely, the first connecting face 9A, is too small;
then the chips are hindered from flowing smoothly.
Further, in such cases; since
the radius of curvature r1 of the second connecting face 8B, needs to be smaller than R1,
or
the radius r2 of the circle inscribed in the straight lines forming the second connecting
face 9B, needs to be smaller than R2;
chip clogging and/or stress concentration may arise.
On the other hand, if the radius R1 or R2 is too large; such a radius R1 or R2 will necessitate a reduction of the radius r1 or r2 of the second connecting face 8B or 9B, or an increase in the width of the gash 6.

[0039] The same as the above,
if the radius r1 or r2 of the second connecting face 8B or 9B is too small, chip clogging and/or stress concentration may arise in the second connecting face 8B or 9B.
On the other hand, if the radius r1 or r2 of the second connecting face 8B or 9B is too large, then the radius R1 or R2 of the first connecting face 8A or 9A needs to be larger than such a radius r1 or r2. Thus, the problem of increasing the width of the gash 6 may arise.
Therefore, as in the description of the first and second embodiments given above,
the radius R1 or R2 of the first connecting face 8A or 9A is set in the range of from 0.04×D to 0.08×D, and
the radius r1 or r2 of the second connecting face 9A or 9B is set in the range of from 0.01×D to 0.05×D, preferably:
wherein D is the external diameter of the end cutting edge 7.
[0040] In the above description,
in the first embodiment, both first and second connecting faces have a concave curved shape in a cross-section; and,
in the second embodiment, both first and second connecting faces have a substantially concave curved shape formed with straight lines in a cross-section.
Further, another case is usable:
wherein a cross-section shows that

the first connecting face has a concave curved shape, and the second connecting face has a substantially concave curved shape formed with straight lines; or
the first connecting face has a substantially concave curved shape formed with straight lines, and the second connecting face has a concave curved shape.
In this case,
the radius of the concave curve of the first connecting face, or
the radius of a circle inscribed in the straight lines forming the first connecting face; is larger than
the radius of the concave curve of the second connecting face, or
the radius of a circle inscribed in the straight lines forming the second connecting face.

[Description of Reference Numerals and Signs]

[0041]

1: END MILL BODY
3: CUTTING EDGE PART
4: FLUTE
4A: PERIPHERAL CUTTING EDGE RAKE FACE
5: PERIPHERAL CUTTING EDGE
6: GASH
6A: END CUTTING EDGE RAKE FACE
6B: GASH BOTTOM FACE
6C: GASH WALL FACE
7: END CUTTING EDGE
8A, 9A: FIRST CONNECTING FACE
8B, 9B: SECOND CONNECTING FACE
O: AXIS OF END MILL BODY 1
T: END MILL ROTATING DIRECTION

[0042] R1, r1: RADIUS OF CURVATURE OF CONCAVE CURVE FORMING FIRST OR SECOND CONNECTING FACE 8A OR 8B IN CROSS-SECTION PERPENDICULAR TO INTERSECTING RIDGELINE BETWEEN END CUTTING EDGE RAKE FACE 6A AND GASH BOTTOM FACE 6B
[0043] R2, r2: RADIUS OF CIRCLE INSCRIBED IN LINES FORMING FIRST OR SECOND CONNECTING FACE 9A OR 9B IN CROSS-SECTION PERPENDICULAR TO INTERSECTING RIDGELINE BETWEEN END CUTTING EDGE RAKE FACE 6A AND GASH BOTTOM FACE 6B

Claims

1. An end mill in which
an end mill body rotates on an axis;
a flute is formed in a periphery of a top portion of the end mill body;
a gash is formed in a top portion of the flute;
the gash has a shape which is like a shape formed by cutting out a wall face of the flute which faces an end mill rotating direction;
a wall face of the gash which faces the end mill rotating direction, is an end cutting edge rake face; and
an end cutting edge is formed along a top side ridge portion:
wherein,
a gash bottom face of the gash is formed between the end cutting edge rake face and the wall face of the gash which faces the rear side in the end mill rotating direction;
connecting faces connect the gash bottom face and the end cutting edge rake face, and connect the gash bottom face and the gash wall face;
the connecting faces have a concave curved shape or a substantially concave curved shape formed with straight lines in a cross-section perpendicular to an intersecting ridgeline between the end cutting edge rake face and the gash bottom face;
the connecting face which connects the gash bottom face and the end cutting edge rake face, is a first connecting face;
the connecting face which connects the gash bottom face and the gash wall face, is a second connecting face; and
a radius of curvature of the first connecting face is larger than a radius of curvature of the second connecting face in the above cross-section, or
a radius of a circle inscribed in the straight lines forming the first connecting face is larger than a radius

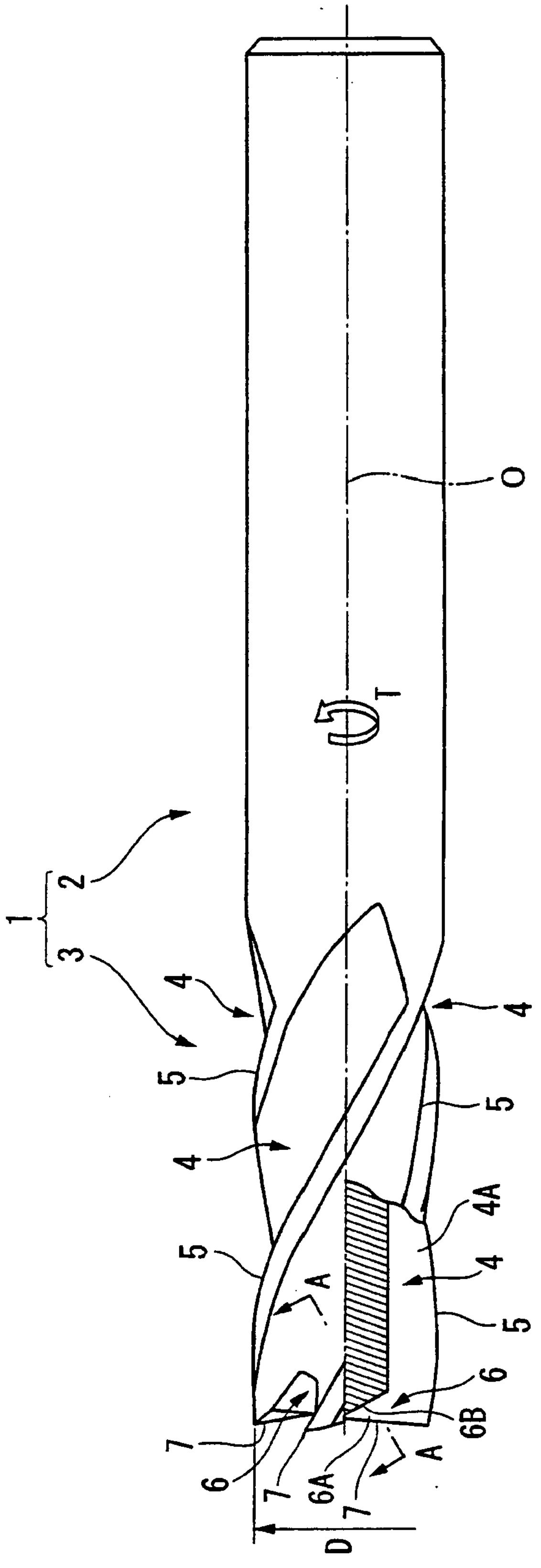
of a circle inscribed in the straight lines forming the second connecting face in the above cross-section.

2. The end mill according to Claim 1 wherein the radius of curvature of the first connecting face is in the range of from $0.04 \times D$ to $0.08 \times D$, or the radius of a circle inscribed in the straight lines forming the first connecting face is in the range of from $0.04 \times D$ to $0.08 \times D$, in the cross-section; and D is the external diameter of the end cutting edge.

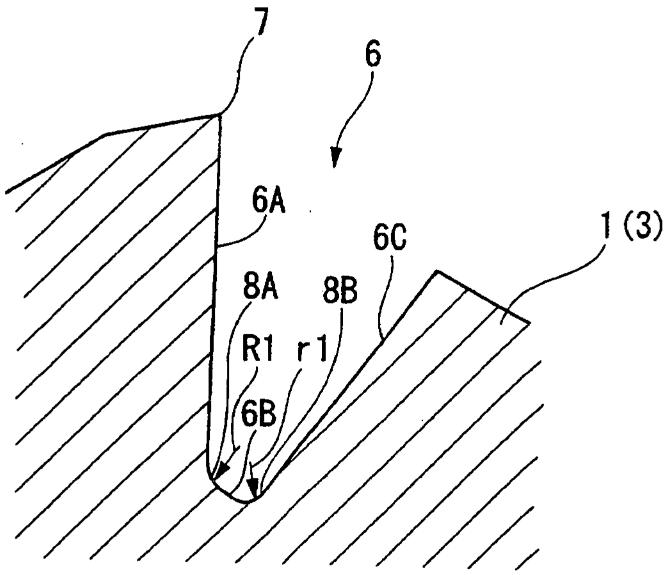
3. The end mill according to Claim 1 or 2, wherein the radius of curvature of the second connecting face is in the range of from $0.01 \times D$ to $0.05 \times D$, or the radius of a circle inscribed in the straight lines forming the second connecting face is in the range of from $0.01 \times D$ to $0.05 \times D$, in the cross-section; and D is the external diameter of the end cutting edge.

4. The end mill according to any one of Claims 1 to 3, wherein three or more end cutting edges are formed at the top of the end mill body.

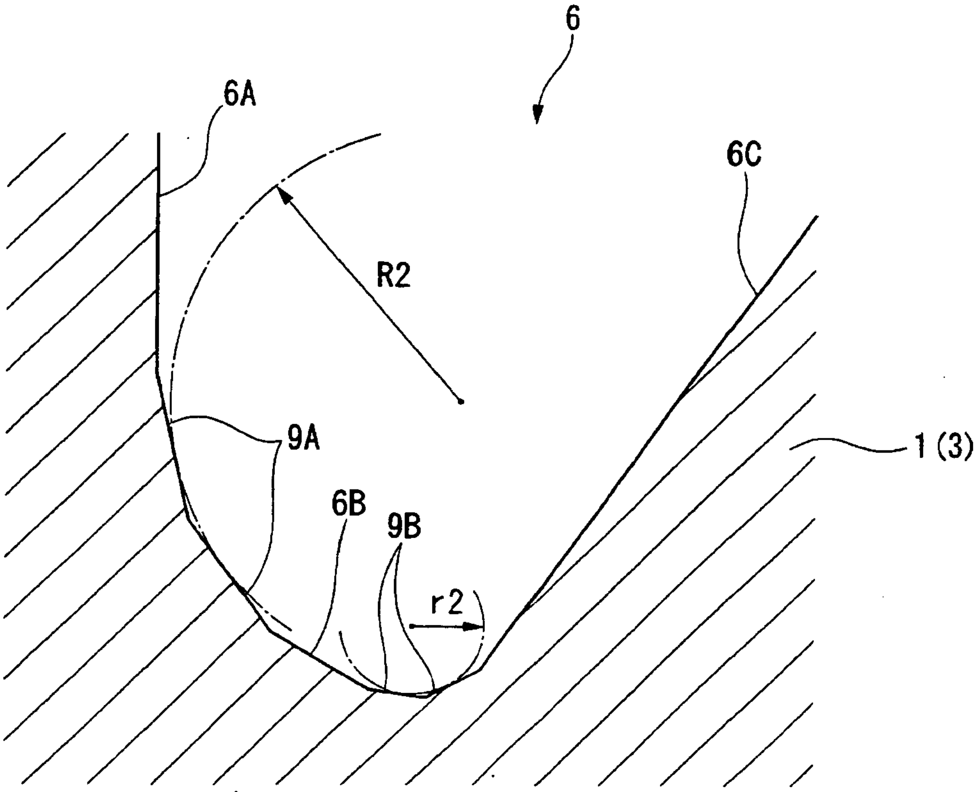
[Fig. 1]



[Fig. 2]



[Fig. 3]



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EUROPEAN SEARCH REPORT

Application Number
EP 10 00 2881

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1

Place of search	Date of completion of the search	Examiner
The Hague	10 June 2010	Rilliard, Arnaud

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